Breaking Barriers: A Look Into the Past, Present, and Future of Dams

Blakely Browne

University of British Columbia

GEOG 211 101

Dr. Loch Brown

Nov. 22, 2016

Introduction

The dam building era began in the United States in the 1890's, with a conglomerate of countries in the Global North tagging closely behind (Everard, 2013). Following a rapid expansion of the technology, countries in the Global South, largely India, began to harness the powers of water as well, with the first Indian dam being constructed in 1902 (2013). From then on, dams continued to be rapidly built, leaping from approximately five thousand in 1950, to more than fifty thousand in 2000 (Isaacman, A., & Isaacman, B., 2013), leading to the current state of the earth, with over 50% of the worlds large rivers being affected by dams (Nilsson, Reidy, Dynesius, & Revenga, 2005). With dams providing an abundance of ecological services to humans (Everard, 2013; Isaacman, A., & Isaacman, B., 2013; Jobin, 1999), they are largely sought after by governments as tools to aid in the development of a society, especially in developing countries where these ecological goods are seen as vital in order to fulfill the goals and standards these nations strive to reach (Isaacman, A., & Isaacman, B., 2013). Due to the fact that the majority of developing nations sit on arid or semi-arid land (United Nations Environment Programme (UNEP), n.d.), dams provide hope in a multitude of sectors, from limiting damages brought by floods, to increasing the potential to irrigate and harvest crops on land not typically suited for agriculture (Lehner et al., 2011; Everard, 2013). Famously, the first prime minster of India, Jawaharlal Nehru, described dams as being "the temples of India" (Everard 2013, p. 28), because of the potential they had to bringing drastic positive change to areas of India susceptible to drought and therefore famine. While the building of dams is typically framed as positive due to its ability to bring electrical power and other ecological goods to populations, a multitude of negative effects to both human populations and the environment are included in the package. In

this paper, I will utilize the Driving Forces-Pressures-State-Impacts-Responses (DPSIR) model (omitting a specific "pressures" section because I am treating dams themselves as being the pressure) created by the UNEP to in turn analyze how and in what ways dams have led to the current state of the environment. Then, I will propose ideas of what can be done in the future to minimize the impacts dams are having on aquatic ecosystems, and the entire of global ecology alike.

Driving Forces

The construction of dams is directly related to a series of drivers, of which urge governments to prioritize their continued development. I will discuss two main influences that lead to the construction of dams: 1. Population growth; and 2. A desire to progress.

The world's growing population is a large driver for the continued construction of dams. Due to a drastic increase in the quantity of humans on Earth since the beginning of the 20th century, leaping from 1.6 billion in 1900, to the more than 7 billion that are living today, governments have looked to dams for the increased power and irrigation they provide, so that their populations have access to electricity, food, and a consistent water source (Chen, Shi, Sivakumar, & Peart, 2016). Looking at population densities of countries, they roughly correlate with the number of large dams in use. The most populated countries, from largest population to smallest, are China (1,376,049,000), India (1,311,051,000), and the United States (321,774,000) (United Nations (UN), 2015). Looking at China, which has seen rapid development in the past 30 years (UN, 2016), the number of large dams comes in at 23,842, which is more than double that of the second most densely dammed country, the United States, at 9,265. India comes in with the third most, at 5,102 large dams (International Commission on Large Dams (ICOLD, n.d.). The

fact that water utilized for agriculture makes up 70% of the global water usage (Chen et al., 2016) displays that with an increasing population comes an increased demand for readily accessible water, which is found most easily in reservoirs created by dams. Since countries seeing the largest population growth are in the Global South (UN, 2015), where arid and semi-arid landscapes are more common, ruling bodies see it as a necessity to construct dams to make the land more liveable (Everard, 2013). The reservoirs created allow a country to irrigate and provide a consistent freshwater source for its population. Water is vital to human life, and it is therefore essential to have in close proximity to settlements. With dams providing agricultural benefits, access to freshwater, potential locations for commercial fishing, and recreational areas, they are seen as a worthy investment for developing countries (2013).

Masked behind population growth and all other factors leading to the development of dams is a global drive by countries to increase energy production, as this correlates with what can be conceived as possessing a more modernized or advanced state that in turn has the potential to be more successful and productive in the current, capitalist world economy (Isaacman, A., & Isaacman, B., 2013). Mark Everard states it well in his book Hydropolitics of Dams: Engineering or Ecosystems?, saying, "Water is life. It is also power, opportunity, influence and status, particularly for those controlling it in arid and water stressed lands" (2013, p. 1). With the globalization of the theory of modernity, and an adoption of similar ideas of progress, the drive to construct dams has become a worldwide development initiative, with the technologies rapidly expanding throughout both the Global North and South. As countries in the global south follow the linear path of progression that has been laid out for them by the global north, typically seen as, "industrialization, urbanization, education, communication,

mobilization, and political incorporation" (Przeworski & Limongi, 1997), they in turn require a larger base of available energy so that they can expand economically, and their population can reap the same benefits individuals in the global north already have access to.

Impacts

The pressures induced by the construction of dams leads to a variety of impacts on the state of the environment, encompassing a vast span of social and ecological issues.

In regards to social issues, dams have been associated with large displacements of populations, of which are commonly peoples that suffer from the power dynamics that exist in their country of residence. As Allen and Barbara Isaacman discuss in Dams, Displacement, and the Delusion of Development, dams are typically situated in positions of power, where there is low capacity for local groups to voice opinions, as they are silenced by collectives of higher power with the ability to sideline them (2013). While dams produce approximately 16% of global energy (International Energy Agency (IEA), 2016), providing for large portions of the population, settlements up and downstream from building sites can be negatively effected. The creation of reservoirs upstream of dams, and the shifted water patterns downstream lead to the forced relocation of individuals, in some cases threatening their very ways of life (Isaacman, A., & Isaacman, B., 2013). An example exists in Mozambique, where when the Cahora Bassa Dam was installed on the Zambezi River, the Shona and other Chewa speaking people of the land who made home along the banks were displaced. This effected them in drastic ways, due to the fact that the river was their primary form of "wealth" providing the group with water to drink, wash, cook, and travel on so inter-community trade could occur (2013). Deforestation is commonly

associated with dam building (Jobin, 1999), and the tree removal that took place in this instance removed a vital natural resource to the displaced peoples, of which they utilized to create canoes and housing (Isaacman, A., & Isaacman, B., 2013). The issue of displacement is predominantly a problem in countries ruled by, or in the wake of an occupation by a colonizing power, due to the fact that the colonialist regimes possess a larger capacity to over-power groups existing in the area prior to contact (2013).

Dams cause a multitude of environmental issues, ultimately manifesting in "[shifted] river temperature regimes, timing of hydrology, alteration of food webs… [and] habitat modification" (Everard 2013, p. 44). The reservoirs dams produce are especially worrisome, possessing a plethora of environmental issues in themselves. While frequently considered to be producers of clean energy, dams do in fact contribute to a decline in air quality due to an increase in methane production from the reservoirs they create, produced by microbial activity in sediments and vegetation a dams reservoir flows over, globally producing a heating effect equivalent to that of 7.5 billion tonnes of CO_2 (Beaulieu, Smolenski, Nietch, & Townsend-Small, 2014). For comparison, the total US output of CO_2 from the burning of fossil fuels is 5.4 billion tonnes (U.S. Energy Information Administration (EIA), 2014). If more dams are built, increasing the number of reservoirs and therefore methane being produced, issues born from the warming of the earth such as loss of biodiversity, rises in sea levels, and human displacements due to climate shifts (UNEP, 2012), will continue, even potentially faster. In addition, reservoirs and the irrigation they commonly provide in turn lead to multiple other factors lending to a declining state of the environment. The salinization of soil caused by irrigation in arid agricultural land increases the risk for increased cases of large scale famine, since a lack in the potential to grow

and maintain a sustainable supply of crops develops (Jobin, 1999). In addition, the installation of reservoirs in turn allows for more waterborne illnesses to arise, because of an increased capability for disease carrying organisms like mosquitos and aquatic snails to grow and flourish in stationary water (1999). This is especially worrisome in areas like the Sahel region of Africa, along with Mesopotamia and the River Nile, where these diseases are especially concentrated and affected by the installation of dams and reservoirs (1999).

State of the Earth

With the state of the earth currently in decline, some argue we are reaching the "tipping point," a point at which we may cross a threshold, meaning we won't be able recover to the pre-environmental degradation state (Bickel, 2013). Seeing this threatening of the environment, the question of where dams fit in rises.

The damming of rivers has led to an increased fragmentation of river systems, modifying flows and ultimately leading to the homogenization of regional river dynamics (Merritt et al., 2007), while also altering "ecosystem processes… affecting aquatic organisms, particularly migratory species" (UNEP, 2012, p. 108). With the installation of dams comes an inherent loss of sedimentary flows as rivers are split between them into segments, through which only water can pass. When >45,000 large dams dominate river systems globally, the amount of sediment travelling to the oceans from continents becomes largely disturbed (Merritt et al., 2007). This loss of sedimentary flow, which causes the homogenization of river dynamics, poses many threats for the future of aquatic ecosystems, ultimately having the potential to lead to vast losses in biodiversity on the global scale (2007). But this biodiversity is not simply lost due to the

homogenization of river systems born from the fragmentation of sedimentary flows; the installation of dams inherently fragments marine habitats as well, manifesting in ecological discontinuity within both dammed rivers, and their connected riparian corridors (Jansson et al., 2005). With this splitting of marine habitats comes the potential for large scale species loss and declines in biodiversity.

The most prevalent and visible example of fragmentation and its effects on river ecosystems is regarding salmon and other migratory river species. Looking at the Klamath River Basin, which runs from the high deserts of Southern Oregon, to the wet and lush climate of Northern California, numbers averaged approximately 880,000 spawning salmon per year prior to its damming, though now it now only sees about 6% of that figure (Blumm & Erickson, 2012). Due to the fact that biodiversity is directly correlated to ecosystem services and the capability to which an ecological system can thrive (UNEP, 2012, p. 135), the loss of migratory species, in this case salmon, in turn has the potential to make dramatic shifts to the entire ecosystem and food web.

Responses and the Future of Dams

In developed countries, the drive to build dams has seen a decrease, due to the known ecological disruptions they bring, lack of locations to build, and the opposition new projects are commonly met by from environmental groups (UNEP, 2012). Though industrialized countries have the highest concentration of dams, developing countries are seeing the highest rate of continued dam construction, so that they can in turn “secure water and electricity supplies” (2012). So, what is the future of dams?

Interestingly, the rate of dam construction fits well on the Environmental Kuznets Curve (EKC), a chart discussed by Jevan Cherniwchan in his article, “Economic Growth, Industrialization, and the Environment”. The EKC is a chart displaying the theory that as a country develops and industrializes, the quantity of pollutants produced increases, until the country reaches a certain point of affluence and technologies become more efficient, when the quantities begin to drop (Stern, 2004). I argue that the presence of active dam building fits this curve, with higher rates of dam construction occurring in developing countries due to a desire and need to harness the power and ecosystem services rivers possess. Once the country reaches the point at which technologies become more efficient and sustainable, and when the political integration shifts, allowing regional populations to have more influence on national decisions, movements towards other forms of renewable energy begin to become prevalent (Cherniwchan, 2012). Currently, in many developing countries, the state of the political system means that most decisions regarding dams never make it to the regional level, but are rather made by the interests present at the national level (Isaacman, A., & Isaacman, B., 2013). The Cahora Bassa Dam in Mozambique again acts to demonstrate an example of this, with local populations not possessing the power and ability to participate in the decision making process due to existing colonial and national interests in the country (2013). When political incorporation of a states population into decision making processes becomes prevalent, usually correlating with the country becoming “developed” (Przeworski & Limongi, 1997), the building of dams can be seen to slow (UNEP, 2012). Once this occurs, oppositional movements by local population may even see dams begin to be destroyed. Examples of this phenomena can be seen in the United States, where dams contribute approximately 26% of the total renewable energy to the nation (USGS, 2014), but a

large push has been made to remove and destroy dams that no longer are in service, or function inefficiently, so that river systems can return to their pre-dammed state (Knight, Rummel, Chouinard, Stoecker & Calhoun, 2014). Examples can be seen in the Elwha Dam (Elhwa River), Condit Dam (White Salmon River) and Hemlock Dam (Trout Creek) in Washington State, which have recently been removed, and others, such as the Klamath River Dam, set to be removed by 2020 (Blum & Erickson, 2012).

Seeing that the popularity of dam building in developed nations has come to a standstill, the issue now shifts to ways in which these dams can be made more efficient, or removed all-together so that ecosystems and sedimentary flows can resume back to their pre-dammed state. In the case of developing countries, since dam construction is seeing continued pursuance, with approximately 250 dams still being constructed per year (Everard, 2013), it may be more vital to invest in and research technological advances that can be made at construction sites to limit damages done on local ecosystems caused by the fragmentation of rivers, salinization of soils, and deforestation. Attempts to aid migratory fish in reclaiming the waters they once swam have seen varied, but overall lacking success (Brown et al., 2013). For example, counting of American Shad fish migrating up three major rivers, the Connecticut, Susquehanna, and Merrimack rivers in the northeastern United States found only 3% of fish to successfully make it past all dams (2013). Alternatively, money could be invested in other forms of renewable energy, such as wind, solar, geothermal, tidal, and biofuels. If alternative sources of energy were invested in, then increased efficiency in irrigation for agriculture would be a necessity, because a large part of why dams are continuing to be constructed is due to growing populations require more food and therefore more agricultural land (UNEP, 2012). By 2050, it is estimated that 70% more food will

be required to feed the growing population, and if dams are to not continue in their construction, the efficiency of water usage in agriculture will need to be a priority (2012).

Conclusion

Dams, in their entirety, are a complicated subject due to the fact that they are largely beneficial to human populations, harnessing energy from a less extractive source than fossil fuels and ensuring a greater potential for sustained agriculture; but they also possess a multitude of issues that have led to a decline in the state of the environment. The future of dam construction seems weary and unpredictable, as developed countries begin to move away from them, and developing countries begin to utilize them with higher frequency. With the current state of the environment, where ecosystems and biodiversity are on a path of decline, the continued construction of dams would contribute to a persistence, and worsening of the conditions already observed. Though, I believe that with a required increase in both energy and agricultural production in the world, we are granted an opportunity, rather than a dilemma. Instead of placing more dams in river systems, further damaging ecosystems on the regional to global scale, movements towards more renewable energy sources could be utilized in developing countries, where they could in fact serve as an example for the Global North, acting as global leaders in the field of renewables. In addition, with a movement away from dams and the systems of irrigation they support, there is potential to research and begin investing in more sustainable forms of agricultural for the Earth's continually growing population.

References

Beaulieu, J., Rebecca L Smolenski, Christopher T Nietch, & Amy Townsend-Small. (2014). High methane emissions from a midlatitude reservoir draining an agricultural watershed. *Environmental Science & Technology, 48*(19), 11100; 11100. Retrieved November 18, 2016.

Bickel, E. J. (2013). Climate engineering and climate tipping-point scenarios. *Environment Systems & Decisions, 33*(1), 152-167. Retrieved November 19, 2016, from doi:http://dx.doi.org.ezproxy.library.ubc.ca/10.1007/s10669-013-9435-8

Blumm, M. C., & Erickson, A. B. (2012, Fall). Dam removal in the Pacific Northwest: lessons for the nation. *Environmental Law*, *42*(4), 1084+. Retrieved November 20, 2016, from from http://go.galegroup.com.ezproxy.library.ubc.ca/ps/i.do?p=LT&sw=w&u=ubcolumbia&v=2.1&it=r&id=GALE%7CA314563259&sid=summon&asid=eb35a318ab171960d4199429391498ae

Chen, J., Shi, H., Sivakumar, B., & Peart, M. R. (2016). Population, water, food, energy and dams. *Renewable and Sustainable Energy Reviews, 56*, 18-28. Retrieved November 18, 2016, from doi:http://dx.doi.org.ezproxy.library.ubc.ca/10.1016/j.rser.2015.11.043

Cherniwchan, J. (2012). Economic growth, industrialization, and the environment. *Resource and Energy Economics, 34*(4), 442-467. Retrieved November 19, 2016, from doi:http://dx.doi.org.ezproxy.library.ubc.ca/10.1016/j.reseneeco.2012.04.004

Everard, M. (2013). Hydropolitics of dams : Engineering or ecosystems? (1st ed.). London: Zed Books. Retrieved November 14, 2016.

International Commission on Large Dams (ICOLD). (n.d.). Number of Dams by Country Members. Retrieved November 20, 2016, from http://icold-cigb.org/GB/World_register/general_synthesis.asp?IDA=206

International Energy Agency (IEA). Energy Atlas. (2016). Retrieved November 21, 2016, from http://energyatlas.iea.org/#!/tellmap/-1118783123

Isaacman, A. F., & Isaacman, B. S. (2013). New African Histories : Dams, Displacement, and the Delusion of Development : Cahora Bassa and Its Legacies in Mozambique, 1965–2007 (1). Athens, OH, US: Ohio University Press. Retrieved November 10, 2016, from http://www.ebrary.com

Jansson, R., Nilsson, C., & Renofalt, B. (2000). Fragmentation of riparian floras in rivers with multiple dams. *Ecology, 81*(4), 899-903. Retrieved November 18, 2016. doi: 10.2307/177165

Jobin, W. R. (1999). Dams and disease: Ecological design and health impacts of large dams, canals, and irrigation systems. London: E & FN Spon.

Knight, B., & Rummel, T. (Directors), & Chouinard, Y., Stoecker, M., Rummel, T., & Calhoun, B. (Producers). (2014, May 9). DamNation [Video file]. In DamNation. Retrieved November 14, 2016, from http://damnationfilm.com

Lehner, B., Liermann, C., Revenga, C., Vörösmarty, C., Fekete, B., Crouzet, P., Wisser, D. (2011). High-resolution mapping of the world's reservoirs and dams for sustainable river-flow management. *Frontiers in Ecology and the Environment, 9*(9), 494-502. Retrieved November 17, 2016, from http://www.jstor.org.ezproxy.library.ubc.ca/stable/23034466

Nilsson, C., Reidy, C., Dynesius, M., & Revenga, C. (2005). Fragmentation and Flow Regulation of the World's Large River Systems. *Science, 308*(5720), 405-408. Retrieved November 15, 2016, from http://www.jstor.org.ezproxy.library.ubc.ca/stable/3841248

United Nations (UN). (2016) Per capita GDP at current prices - US dollars. Retrieved November 20, 2016, from http://data.un.org/Data.aspx?q=china gdp&d=SNAAMA&f=grID:101;currID:USD;pcFlag:1;crID:156

United Nations Department of Economic and Social Affairs (ESA). (2015) World Population Prospects - Population Division - United Nations. Retrieved November 20, 2016, from https://esa.un.org/unpd/wpp/Download/Standard/Population/

United Nations Environmental Programme (UNEP). (2012). *GEO-5: Global environment outlook 2012: The Fifth Global Environment Outlook: Environment for the future we want*. Retrieved November 14, 2016, from http://www.unep.org/geo/GEO5_ebook/

United Nations Environmental Programme (UNEP). (n.d.). General Directorate of State Hydraulic Works. Retrieved November 13, 2016, from http://www.unep.org/dams/documents/default.asp?documentid=482

United States Geological Survey (USGS). (2014). Hydroelectric Power Water Use. Retrieved November 21, 2016, from http://water.usgs.gov/edu/wuhy.html

U.S. Energy Information Administration (EIA). (2015). U.S. Energy-Related Carbon Dioxide Emissions, 2014. Retrieved November 21, 2016, from http://www.eia.gov/

Poff, N. L., Olden, J. D., Merritt, D. M., & Pepin, D. M. (2007). Homogenization of regional river dynamics by dams and global biodiversity implications. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(14), 5732–5737. Retrieved November 19, 2016, from http://doi.org/10.1073/pnas.0609812104

Przeworski, A., & Limongi, F. (1997). Modernization: Theories and Facts. *World Politics, 49*(2), 155-183. Retrieved November 15, 2016, from http://www.jstor.org.ezproxy.library.ubc.ca/stable/25053996

Stern, D. I. (2004). The rise and fall of the environmental kuznets curve. World Development, 32(8), 1419-1439. Retrieved November 15, 2016, from doi:http://dx.doi.org/10.1016/j.worlddev.2004.03.004

Waldman, J. (2013). Blocked Migration: Fish Ladders On U.S. Dams Are Not Effective. Retrieved November 21, 2016, from http://e360.yale.edu/feature/blocked_migration_fish_ladders_on_us_dams_are_not_effective/2636/